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(54) **ARYL-SUBSTITUTED AND/OR
HETEROARYL-SUBSTITUTED MAIN GROUP
ELEMENT HALIDES AND/OR
PSEUDOHALIDES, USE OF MAIN GROUP
ELEMENT HALIDES AND/OR
PSEUDOHALIDES, ORGANIC
SEMICONDUCTING MATRIX MATERIAL,
ELECTRONIC AND OPTOELECTRONIC
COMPONENTS**

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(57) **ABSTRACT**

The invention relates to aryl- and/or heteroaryl-substituted main group element halides and/or pseudohalides, the use of main group element halides and/or pseudohalides as dopant for the doping of an organic semiconducting matrix material, as charge injection layer, as hole blocker layer, as electrode material, as transport material itself, as memory material in electronic or optoelectronic structural elements.

10 Claims, No Drawings

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1

**ARYL-SUBSTITUTED AND/OR
HETEROARYL-SUBSTITUTED MAIN GROUP
ELEMENT HALIDES AND/OR
PSEUDOHALIDES, USE OF MAIN GROUP
ELEMENT HALIDES AND/OR
PSEUDOHALIDES, ORGANIC
SEMICONDUCTING MATRIX MATERIAL,
ELECTRONIC AND OPTOELECTRONIC
COMPONENTS**

CROSS-REFERENCE TO RELATED
APPLICATION

This is a submission pursuant to 35 U.S.C. 154(d)(4) to enter the national stage under 35 U.S.C. 371 for PCT/DE2008/000645 filed Apr. 16, 2008. Priority is claimed under 35 U.S.C. 119(a) and 35 U.S.C. 365(b) to German Patent Application Number 10 2007 018 456.7 filed Apr. 19, 2007. The subject matters of PCT/DE2008/000645 and German Patent Application Number 10 2007 018 456.7 are hereby expressly incorporated herein by reference in their entirety.

The invention relates to aryl- and/or heteroaryl-substituted main group element halides and/or pseudohalides, the use of main group element halides and/or pseudohalides as dopant for the doping of an organic semiconducting matrix material, as charge injection layer, as hole blocker layer, as electrode material, as transport material itself, as memory material in electronic or optoelectronic structural elements as well as to an organic semiconducting material and electronic or optoelectronic structural elements.

The changing of organic semiconductors by doping as regards their electrical properties, especially their electrical conductivity, as is also the case for inorganic semiconductors such as silicon semiconductors, is known. This achieves an elevation of the conductivity, which is quite low at first, as well as, depending of the type of dopant used, a change in the Fermi level of the semiconductor by generating charge carriers in the matrix material. A doping results here in an elevation of the conductivity of charge transport layers, as a result of which ohmic losses are reduced, and in an improved transition of the charge carriers between contacts and organic layer. Inorganic dopants such as alkali metals (e.g., cesium) or Lewis acids (e.g., FeCl₃, SbCl₅) are usually disadvantageous for organic matrix materials on account of their high coefficients of diffusion since the junction and stability of the electronic structural elements is adversely affected, see D. Deter, Ch. Ziegler, W. Göpel *Synthetic Metals* (1993) 61 147-50; Y. Yamamoto et al. (1965) 2015, J. Kido et al. *Jpn J. Appl. Phys.* 41 (2002) L358-60. Moreover, the latter dopants have such a high vapor pressure that a technical use is very questionable. In addition, the reduction potentials of these compounds are often too low for doping technically really interesting hole conductor materials. In addition, the extremely aggressive reaction behavior of these dopants makes a technical application difficult.

The present invention is based on the object of making compounds available that can be used as dopant, as charge injection layer, as hole blocker layer, as electrode material, as transport material itself or as memory material. The compounds should preferably have sufficiently high reduction potentials, be without disturbing influences on the matrix material and make available an effective elevation of the charge carrier number in a matrix material and be able to be relatively simply handled.

Further tasks of the present invention consist in the usage of corresponding compounds as dopant for doping an organic semiconducting matrix material, as charge injection layer, as

2

electrode material, as transport material itself as well as memory material in electronic or optoelectronic structural elements, as well as in the making available of organic semiconducting materials and of electronic structural elements or optoelectronic structural elements in which the disclosed compounds can be used.

The first object is solved by aryl- and/or heteroaryl-substituted main group element halides and/or pseudohalides, characterized by the following structure: R_n-M-X_m, wherein M is a main group element, R is independently selected from non-substituted and electron-acceptor-substituted aryl, heteroaryl, preferably electron-poor heteroaryl, and —Z-MR_nX_m, wherein Z is selected from O, S, alkylene, NR₁ with R₁=CN, halogen, alkyl, heteroalkyl or aryl, O—(R₂)_x—O with R₂=alkyl or aryl and with x=1-6, wherein X is independently selected from halogen and pseudohalogen, n=1-6 and m=1, 2, 3, 4, or 5, or wherein the groups R are connected to each other at least in pairs, directly or via a bridge, preferably via O, S or alkylene, with the following compounds being excluded: (1,4-Dihydro-1-phenyl-5H-tetrazole-5-thionato-N4)bis(pentafluorophenyl)SbNCSCl; Bis(pentafluorophenyl)(4-tolyl)antimony (V)dichloride; Hexa(4-trifluoromethylphenyl)tellurium(VI); Penta(4-trifluoromethylphenyl)tellurium(VI)chloride; Penta(4-trifluoromethylphenyl)tellurium(VI) bromide; Bis([1,1'-biphenyl]-2,2'-diyl)seleniumdifluoride; Bis([1,1'-biphenyl]-2,2'-diyl)telluriumdifluoride; Bis([1,1'-biphenyl]-2,2'-diyl)telluriumdichloride; Tetraphenyltellurium(VI)difluoride; Tri(pentafluorophenyl)tellurium(IV)halide; Tri(pentafluorophenyl)tin(IV)halide; Tri(pentafluorophenyl)germanium (IV)halide; Tri(pentafluorophenyl)silicon(IV) halide; Bis(pentafluorophenyl)germanium(IV)dihalide; Bis(pentafluorophenyl)tellurium(IV)dihalide; Bis(pentafluorophenyl)M(IV)dihalide with M=Si, Se, S; Bis(pentafluorophenyl)tin(IV)dichloride; Bis(pentafluorophenyl)tin(IV)dibromide.

It should be noted regarding the structure of the main group element halides and/or pseudohalides shown in the claims that these compounds have at least one group ft, so that n≥1.

In accordance with the valence of the main group elements. e.g., the following substructures can fall under the structure shown in the claims:

If the central atom M is, e.g., S, Se or Te, then a structure R₁₋₆-M-X₀₋₅ can result. If the central atom M is, e.g., P, As, Sb or Bi, a structure R₁₋₅-M-X₀₋₄ can result. If the central atom M is, e.g., Al, Ga, In, Tl, P, As, Sb or Bi, a substructure R₁₋₃-M-X₀₋₂ results. If the central atom M is, e.g., Si, Sn, S, Se, Te or Pb, a substructure R₁₋₄-M-X₀₋₃ results.

These aryl- and/or heteroaryl-substituted main group element halides and/or pseudohalides can also be used as hole injection layer. Thus, e.g., a layer structure anode/acceptor/hole transporter can be produced. The hole transporter can be a pure layer or a mixed layer. In particular, the hole transporter can also be doped with an acceptor. The anode can be, e.g., ITO. The acceptor layer can be, e.g., 0.5-100 nm thick.

It was surprisingly determined that given a use in accordance with the invention of the disclosed main group element halides and/or pseudohalides a significantly stronger and/or more stable dopant is present than in the case of previously known acceptor compounds, wherein the main group element halides and/or pseudohalides are used in neutral form as p-dopant in an organic semiconducting matrix material. What was stated above applies in particular to aryl- and/or heteroaryl-substituted main group element halides and/or pseudohalides. In particular, the conductivity of charge carrier transport layers is significantly increased in the usage in accordance with the invention and/or the transition of the

charge carriers between the contacts and organic layer is significantly improved in applications as electronic structural element. Without being limited to this concept, it is assumed that in the usage of the main group element halides and/or pseudohalides in accordance with the invention in a doped layer CT complexes are formed, in particular by the transfer of at least one electron of the particular surrounding matrix material. Likewise, cations of the matrix material are formed that can move on the matrix material. In this manner the matrix material gains a conductivity that is elevated in contrast to the conductivity of the non-doped matrix material. Conductivities of non-doped matrix materials are as a rule $<10^{-8}$ s/cm, especially frequently $<10^{-10}$ s/cm. Care is to be taken here that the matrix material has a sufficiently high purity. Such purities can be achieved with traditional methods, e.g., gradient sublimation. The conductivity of such matrix materials can be increased by doping to greater than 10^{-8} s/cm, frequently $>10^{-5}$ s/cm. This applies in particular to matrix materials that have an oxidation potential greater than -0.5 V vs. Fc/Fc^+ , preferably greater than 0 V vs. Fc/Fc^+ , especially greater than $+0.2$ V vs. Fc/Fc^+ . The indication Fc/Fc^+ refers to a redox pair ferrocene/ferrocenium that is used as reference in an electrochemical determination of potential, e.g., cyclic voltammetry.

According to the invention it was furthermore established that in particular the described aryl- and/or heteroaryl-substituted main group element halides and/or pseudohalides can also be used as injection layer in electronic structural parts, preferably between an electrode and a semiconductor layer that can also be doped, or also as blocker layer, preferably between emitter layer and transport layer in electronic structural elements. The compounds used in accordance with the invention have a surprisingly high stability relative to their reactivity with the atmosphere.

Preparation of the aryl- and/or heteroaryl-substituted main group element halides and/or pseudohalides.

The described aryl- and/or heteroaryl-substituted main group element halides and/or pseudohalides can be synthesized according to known processes. The synthesis of such compounds is described, e.g., in the following literature passages, that are included herewith to their full extent as reference in the application. It is understood that the cited literature passages are indicated only by way of example. The preparation of alkyl- and/or heteroalkyl-substituted compounds takes place in an analogous manner. According to O. Glemser et al., e.g., triaryl compounds of arsenic, phosphorus and antimony can be prepared from the corresponding Grignard compounds and the main group trichlorides, see *Angew. Chem.* (1964) 76 953; Alonso R. A. et al., *JOC* (1982) 47(1) 77-80; Fausett B. W. (2005) 70(12) 4851-3. The triaryl compounds obtained in this manner can be oxidized with pure or mixed dihalogen or, e.g., with TeCl_4 to dihalogentriaryl compounds, G. S. Harris, A. Kahn, I. Lennon, *J. Fluorine Chem.* 37 (1987) 247-52; S. N. Bhattacharya, M. Singh, *Indian J. Chem.* 16A (1978) 778-81; A. Ouchi et al. (1975) 74-99. The halogen groups can be subsequently substituted by other halogen or pseudohalogen groups, A. Otero, P. Royo, *J. Organometallic Chem.* 154 (1978) 13-9, or by means of aryl or heteroaryl metals such as, e.g., phenyllithium in pentaaryl or -heteroaryl compounds, Barton D. H. R. et al., *J. Chem. Soc. Chem. Comm.* (1980) 17 827-9. Moreover, the triaryl compounds can also be reacted with the corresponding trihalogen

compounds to monohalogen or pseudohalogen diaryl or diheteroaryl main group metallic compounds, Bamgboye T. T. C. *J. Organometallic Chem.* (1989) 362 (1-2) 77-85. Oxygen-bridged aryl main group element compounds are described by M. N. Gibbons and D. B. Sowerby, phosphorus, sulfur, silicon (1994) 93-4 305-8. Tellurium compounds arylated six times can be produced, e.g., directly from bromine aryls and tellurium tetrachloride in the presence of butyl lithium, see *Angew. Chem. Int. Edit.* 35(22) 2660-2 (1996); *Chem.-A European J.* 10(10)2590-2600(2004). The following literature passages can be named as a sample with bridged R groups, *JACS* 128(21) 6778-9 (2006).

Synthesis of Triaryl and Heteroaryl Antimony Dichlorides

Synthesis of tris(pentafluorophenyl)antimony dichloride

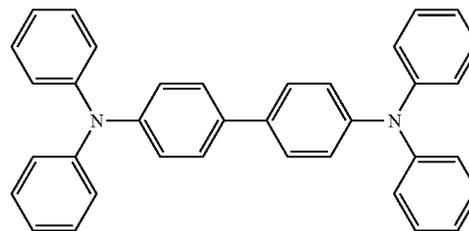
A mixture of 1.5 mmol iodine chloride and 10 ml acetonitrile is slowly added drop by drop to a solution of 1.5 mmol tris(pentafluorophenyl)stilbene in 10 ml acetonitrile under agitation at room temperature. The white crystalline product was obtained from the brown solution after the addition of ether in 65% yield. Fp: $242-4^\circ$ C.

Synthesis of tris(tetrafluoropyridyl)antimonydichloride

A mixture of 1.5 mmol iodine chloride and 10 ml acetonitrile is slowly added drop by drop to a solution of 1.5 mmol tris(tetrafluoropyridyl)stilbene in 10 ml acetonitrile under agitation at room temperature. The white crystalline product was obtained from the brown solution after the addition of ether in 72% yield. Fp: $242-4^\circ$

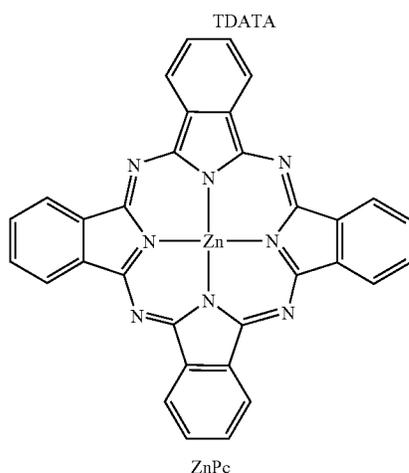
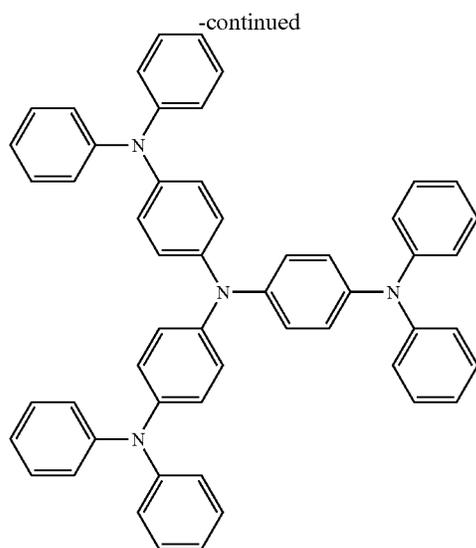
Doping

Among others, phthalocyanine complexes, e.g., of the Zn (ZnPc), Cu (CuPc), Ni (NiPc) or other metals can be used as p-dopable matrix materials, wherein phthalocyanine ligand can also be substituted. Other metal complexes of naphthocyanines and porphyrines can also be used optionally. Furthermore, arylated or heteroarylated amines or benzidine derivatives can also be used that can be substituted or non-substituted, e.g., TPD, a-NPD, TDATA, especially also spiro-linked ones such as, e.g., spiro-TTB. In particular, a-NPD and spiro-TTD can be used as matrix material.



TPD

5



In addition to polyaromatic hydrocarbons, heteroaromatics such as, in particular imidazole, thiazole derivatives, heterotriphenylenes but also others can also be used as matrix material, optionally even dimeric, oligomeric or polymeric heteroaromatics. The heteroaromatics are preferably substituted, especially aryl-substituted, e.g., phenyl-substituted or naphthyl-substituted. They can also be present as spiro compounds.

It is understood that the mentioned matrix materials can also be used mixed with each other or with other materials in the scope of the invention. It is understood that suitable other organic matrix materials that have semiconducting properties can also be used.

Doping Concentration

The dopant is preferably present in a doping concentration of $\leq 1:1$ to the matrix molecule or to the monomeric unit of a polymeric matrix molecule, preferably in a doping concentration of 1:2 or less, especially preferably of 1:5 or less or 1:10 or less. The doping concentration can be in the range of 1:1 to 1:100,000, especially in the range of 1:5 to 10,000 or 1:1.0 to 1,000, e.g., in the range of 1:10 to 1:100 or 1:25 to 1:50 without being limited thereto.

Carrying Out of the Doping

The doping of the particular matrix material with the compounds to be used in accordance with the invention can take place by one or a combination of the following processes:

6

Mixed evaporation in a vacuum with a source for the matrix materials and one for the dopant.

Sequential depositing of the matrix material and of the p-dopant on a substrate with the subsequent diffusing in of the dopant, in particular by thermal treatment.

Doping of a matrix layer by a solution of p-dopant with subsequent evaporation of the solvent, in particular by thermal treatment.

Surface doping of a matrix material layer by a layer of dopant applied on the surface.

Production of a solution of matrix molecules and dopants and subsequent production of a layer from the solution by conventional methods such as, e.g., evaporation of the solvent or centrifuging it on.

The doping can also optionally take place in such a manner that the dopant is evaporated from a precursor compound that releases the dopant upon being heated and/or irradiated. For example, a carbonyl compound, dinitrogen compound or the like that are split off during the release of the dopant CO, nitrogen or the like can be used as precursor compound with other suitable precursors also being able to be used such as, e.g., salts, e.g., halides or the like. The heat necessary for the evaporation can substantially be made available by an irradiation which can also be irradiated in a targeted manner into certain bands of the compounds and/or precursors or compound complexes such as charge-transfer complexes in order to facilitate the evaporation of the compounds by dissociation of the complexes, e.g., by conversion into excited states. However, the complex can in particular also be sufficiently stable to evaporate in a non-dissociated manner under the given conditions or to be applied onto the substrate. It is understood that other suitable processes can also be used to carry out the doping.

Thus, in this manner p-doped layers of organic semiconductors can be produced that can be used in many different ways.

Semiconducting Layer

Semiconducting layers can be produced by the main group element halides and/or pseudohalides, which layers are optionally preferably designed to be linear such as, e.g., conductivity paths, contacts or the like. The main group element halides and/or pseudohalides can be used here as p-dopants together with another compound that can function as matrix material, wherein the doping ratio can be 1:1 or less. However, the dopant used can also be present in higher amounts relative to the particular compound or component so that the ratio of dopant:compound can be in a ratio $>1:1$, e.g., in a ratio of $\geq 2:1$, $\geq 5:1$, $\geq 10:1$ or $\geq 20:1$ or higher. The particular other component can be one such as is used as matrix material in the ease of the production of doped layers, without being limited thereto. The dopant use can also be optionally present in pure form, e.g., as pure layer.

The area containing a dopant or consisting substantially or completely of the latter can be contacted in an electrically current-conductive manner with an organic semiconducting material and/or an inorganic semiconducting material, e.g., arranged on such a substrate.

In particular the mentioned electron-poor aryl-substituted and/or heteroaryl-substituted main group element halides and/or pseudohalides are preferably used in accordance with the invention as p-dopants, e.g., in a ratio of $\leq 1:1$ or $\leq 1:2$. Semiconducting layers with conductivities at room temperature in the range of 10^{-5} s/cm or higher, e.g., of 10^{-3} s/cm or higher, e.g., of 10^{-2} s/cm can be achieved by the electron-poor compounds used in accordance with the invention as p-dopants, e.g., when using ZnPe, Spiro-TTB or a-NPD as matrix. When using phthalocyanine zinc as matrix a conduc-

tivity of higher than 10^{-8} s/cm was achieved. e.g., 10^{-6} s/cm. The conductivity of non-doped phthalocyanine zinc on the other hand is maximally 10^{-10} s/cm.

It is understood that the layer or the structure with the dopants can contain one or several main group element halides or pseudohalides.

Electronic Structural Element

A plurality of electronic structural elements or equipment containing them with a p-doped organic semiconducting layer can be produced using the described compounds for producing p-doped organic semiconducting materials that can be arranged in particular in the form of layers or electrical line paths. In the sense of the invention the concept "electronic structural elements" also includes optoelectronic structural elements. The electronic properties of an electronically functionally active area of the structural element such as its electrical conductivity, light-emitting properties or the like can be advantageously changed by the use of the described compounds. Thus, the conductivity of the doped layers can be improved and/or the improvement of the charge carrier injection of contacts into the doped layer can be achieved.

The invention comprises in particular organic light-emitting diodes (OLED), organic solar cells, field-effect transistors, organic diodes, in particular those with a high rectification ratio such as 10^3 - 10^7 , preferably 10^4 - 10^7 or 10^5 - 10^7 , and field-effect transistors manufactured by the electron-poor aryl-substituted and/or heteroaryl-substituted material elementary halides and/or pseudohalides.

A p-doped layer based on an organic matrix material, e.g., in the following layer structures can be present in the electronic structural element, the base materials or matrix materials of the individual layers preferably being organic:

p-i-n: p-doped semiconductor-intrinsic semiconductor-n-doped semiconductor,

n-i-p: n-doped semiconductor-intrinsic semiconductor-p-doped semiconductor.

"i" is a non-doped layer again, "p" is a p-doped layer. The contact materials are hole-injecting here, wherein on the p side, e.g., a layer or a contact of ITO or Au can be provided, or electron-injecting, wherein on the n side a layer or a contact of ITO. Al or Ag can be provided.

In the above structures the i layer can also be omitted if required, as a result of which layer sequences with p-n or n-p transitions can be obtained.

However, the use of the described compounds is not limited to the above-mentioned exemplary embodiments, in particular the layer structures can be supplemented or modified by the introduction of additional suitable layers. In particular, OLEDs with such layer sequences, in particular with pin structure or with a structure inverse to it, can be built up with the described compounds.

In particular, organic diodes of the type metal-insulator-p-doped semiconductor (min) or also, optionally, of the pin type can be produced with the aid of the described p-doping agents, e.g., based on phthalocyanine zinc. These diodes display a rectification ratio of 10^5 and higher. Furthermore, electronic structural elements with p-n transitions can be produced using the mentioned compounds, wherein the same semiconductor material is used for the p-doped side and the n-doped side (homo-p-n transition), and wherein a described electron-poor aryl-substituted and/or heteroaryl-substituted main group element halides and/or pseudohalide is used with particular preference for the p-doped semiconductor material.

However, the electron-poor aryl-substituted and/or heteroaryl-substituted main group element halides and/or pseudohalides can also be used in accordance with the inven-

tion in the electronic structural elements in layers, conductivity paths, point contacts or the like if the latter predominate relative to another component, e.g. as injection layer in pure or in the substantially pure form.

Further tasks and advantages of the present invention will now be described in an illustrating manner using the following examples that are to be considered as only illustrative and not as limiting the scope of the invention.

EXAMPLES OF APPLICATION

An extremely electron-poor aryl-substituted and/or heteroaryl-substituted main group element halide or pseudohalide is provided in a very clean manner.

The presented electron-poor aryl-substituted and/or heteroaryl-substituted main group element halide or pseudohalide is evaporated at the same time with the matrix material. According to the exemplary embodiment the matrix material is phthalocyanine zinc, spiro-TTB or a-NDP. The p-dopant and the matrix material can be evaporated in such a manner that the layer precipitated on a substrate in a vacuum evaporation system has a doping ratio of p-dopant to matrix material of 1:10.

The layer of the organic semiconducting material doped with the p-dopant is applied on an ITO layer (indium tin oxide) arranged on a glass substrate. After application of the p-doped organic semiconducting layer a metal cathode is applied, e.g., by evaporation of a suitable metal, in order to produce an organic light-emitting diode. It is understood that the organic light-emitting diode can also have a so-called inverted layer design, wherein the layer sequence is: glass substrate-metal cathode-p-doped organic layer-transparent conductive cover layer (e.g., ITO). It is understood that further layers can be provided between the individual mentioned layers, depending on the application.

Example 1

Tris(pentafluorophenyl)antimony dichloride

The neutral antimony compound was used for the doping of ZnPc as matrix material. Doped layers with a doping ratio of doping agent:matrix material of 1:10 were produced by mixed evaporation of matrix and doping agent with ZnPc. The conductivity was 3×10^{-4} S/cm.

Example 2

Tris(pentafluorophenyl)antimony dichloride

The neutral antimony compound was used for the doping of spiro-TTB as matrix material. Doped layers with a doping ratio of doping agent:matrix material of 1:10 were produced by mixed evaporation of matrix and doping agent with spiro-TTB. The conductivity was 3×10^{-7} S/cm.

Example 3

Tris(tetrafluoropyridyl)antimony dichloride

The neutral antimony compound was used for the doping of ZnPc as matrix material. Doped layers with a doping ratio of doping agent:matrix material of 1:10 were produced by mixed evaporation of matrix and doping agent with ZnPc. The conductivity was 3.1×10^{-4} S/cm.

Example 4

Tris(tetrafluoropyridyl)antimony dichloride

The neutral antimony compound was used for the doping of spiro-TTB as matrix material. Doped layers with a doping ratio of doping agent:matrix material of 1:10 were produced by mixed evaporation of matrix and doping agent with spiro-TTB. The conductivity was 1.8×10^{-7} S/cm.

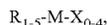
The features of the invention disclosed in the previous description and in the claims can be essential for the realization of the invention in its different embodiments both individually as well as in any combination.

The invention claimed is:

1. An organic semiconducting material comprising at least one organic matrix compound and one dopant, wherein the dopant is a p-dopant having the following structure:



wherein M is selected from S, Se, or Te; or



wherein M is selected from P, As, Sb, or Bi;

wherein each R is independently selected from the group consisting of substituted or non-substituted aryl or substituted or non-substituted heteroaryl;

wherein X is independently selected from halogen or pseudohalogen;

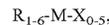
wherein the sum of the two subscripts representing the number of R and X substituents is (i) equal to 6 if M is selected from S, Se, or Te, or (ii) equal to 5 if M is selected from P, As, Sb, or Bi; and

wherein any of groups R may be connected to each other at least in pairs, directly or via a bridge.

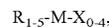
2. The organic semiconducting material according to claim 1, wherein a molar doping ratio of the dopant to a matrix molecule of the at least one organic matrix compound is between 20:1 and 1:100,000, wherein when the at least one organic matrix compound is a polymer, the matrix molecule is a monomeric unit of the polymer.

3. An electronic or optoelectronic structural element comprising at least one main group element halide and/or pseudohalide as a p-dopant for doping an organic semiconducting matrix material, a charge injection layer, a hole blocker layer, an electrode material, a transport material, or a

memory material, wherein the main group element halide and/or pseudohalide has the following structure:



wherein M is selected from S, Se, or Te; or



wherein M is selected from P, As, Sb, or Bi;

wherein each R is independently selected from the group consisting of substituted or non-substituted aryl or substituted or non-substituted heteroaryl;

wherein X is independently selected from halogen or pseudohalogen;

wherein the sum of the two subscripts representing the number of R and X substituents is (i) equal to 6 if M is selected from S, Se, or Te, or (ii) equal to 5 if M is selected from P, As, Sb, or Bi; and

wherein any of groups R may be connected to each other at least in pairs, directly or via a bridge.

4. The electronic or optoelectronic structural element according to claim 3, wherein one or more of the substituted or non-substituted aryl or substituted or non-substituted heteroaryl substituents is substituted independently with halogen and/or acceptor substituents.

5. The electronic or optoelectronic structural element according to claim 3, wherein the halide and/or pseudohalide further comprises at least one neutral co-ligand.

6. The electronic or optoelectronic structural element according to claim 3, wherein X is selected from CN, OCN, SCN, or N_3 .

7. The electronic or optoelectronic structural element according to claim 3, wherein X is Cl.

8. The electronic or optoelectronic structural element according to claim 3, comprising an electronically functional active area, wherein the active area comprises the main group element halide and/or pseudohalide.

9. The electronic or optoelectronic structural element according to claim 8, wherein the electronically active area comprises an organic semiconducting matrix material that is doped with the at least one p-dopant for changing the electronic properties of the semiconducting matrix material.

10. The electronic or optoelectronic structural element according to claim 3, wherein the element is in the form of an organic light-emitting diode, a photovoltaic cell, an organic solar cell, an organic diode, an organic field-effect transistor or a photo-initiated or magnetic memory.

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